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APPLICATION OF ANAEROBICALLY DIGESTED BIOSOLIDS TO DRYLAND SUNFLOWERS 2014 RESULTS

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INTRODUCTION

Over 40% of biosolids are land applied in the U.S. (Brobst, Robert. 2011. USEPA, Personal Communication). Land application can greatly benefit municipalities and farmers by recycling plant nutrients in an environmentally sound manner (Barbarick et al., 1992).

Our long-term biosolids project, now in its 34th year, has provided information on the effects of continuous biosolids applications to dryland winter wheat (*Triticum aestivum* L.). Previous research has shown that Littleton/Englewood biosolids are an effective alternative to commercial N fertilizer with respect to grain production and nutrient content of winter wheat (Barbarick et al., 1992). As with other N fertilizers, however, application rates of biosolids exceeding the N needs of the crop result in an accumulation of soil nitrate-nitrogen. Excess soil nitrate-nitrogen may move below the root zone or off-site and contaminate groundwater or surface waters. The potential benefit of biosolids is that they contain organic N, which can act as a slow-release N source and provide a more constant supply of N during the critical grain-filling period versus typically used commercial N fertilizer sources. They can also furnish significant amounts of plant available P, Zn, and Fe.

Following the harvest of winter wheat in the summer of 2013, it was decided that a summer crop should be planted to allow the use of different herbicides to control a jointed goat grass (*Aegilops cylindrica* Host) problem that had developed at the experimental site.. Therefore wheat was not planted in the fall of 2014, and instead, confection sunflowers (*Helianthus annuus* L.) were planted in the spring of 2014.

For the Littleton/Englewood biosolids, a 2 dry tons biosolids A^{-1} application rate will supply approximately 32 lbs N A^{-1} over the growing season (Barbarick and Ippolito, 2000; Barbarick and Ippolito, 2007), an amount within the typical application range for dryland winter wheat crops in our study area. Other biosolids sources may exhibit a different N fertilizer equivalency. Previous research has shown no detrimental grain trace-metal accumulation with this application rate (Barbarick et al., 1995). Therefore, we continue to recommend a 2 dry tons biosolids A^{-1} rate as the most sustainable land-application rate for biosolids with similar nutrient characteristics and for similar crop yields. Even though sunflowers were being grown, it was decided to continue the application of biosolids and N fertilizer at the same rates as for wheat to maintain the long-term consistency of the study.

The change in crop allowed for the comparison of the effects of Littleton/Englewood (L/E) biosolids and commercial N fertilizer rates on: a) dryland sunflowers grain production, b) sunflower seed total nutrient and trace-metal content, and c) soil NO_3-N accumulation and movement.

MATERIALS AND METHODS

The North Bennett experimental plots were established in August 1993, and the soil is classified as a Weld loam, Aridic Argiustoll. The land is managed with minimum-tillage practices. Precipitation amounts are shown in Table 1.

We applied N fertilizer (46-0-0; urea) at rates of 0, 20, 40, 60, 80, and 100 lbs N A^{-1} and biosolids (93% solids, Table 2) at rates of 0, 1, 2, 3, 4, and 5 dry tons A^{-1} in July 2014. The same plots received biosolids and N fertilizer, at the above rates, in July or August 1994, 1996, 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012, and 2014. According to the 1996 Colorado Department of Public Health and Environment Biosolids Regulations, L/E biosolids are classified as Grade I and are suitable for application to agricultural and disturbed lands (Table 2). We uniformly applied both biosolids and N fertilizer and the materials were surface incorporated by hand raking. The North Bennett site was cropped with the winter wheat cultivar 'TAM 107' during the 1993-4, 1995-6, and 1997-8 growing seasons, 'Prairie Red' during the 1999-2006 seasons, 'Ripper' from 2007-12, 'Prowers99' in 2013, and confection sunflowers (variety unknown) in 2014.

At harvest we measured seed yield and protein content. We counted the number of plants in each plot and then collected three representative sunflower heads from each plot November 2014 to determine biomass and grain yields. Plant P, Cu, Ni, and Zn concentrations were determined in nitric-acid digests (Huang and Schulte, 1985) using an inductively coupled plasma-atomic emission spectrophotometer (ICP-AES; Soltanpour et al., 1996).

A soil sample was collected from each plot in depth increments of 0 to 8 and 8 to 24 inches. We used ammonium bicarbonate diethylenetriaminepentaacetic acid (AB-DTPA) to extract the soils and determine plant-available P, Cu, Ni, and Zn using the ICP-AES (Barbarick and Workman, 1987). We also collected soil samples from the 0-8, 8-24, 24-40, 40-60, and 60-80-inch depths in the control, 40 lbs N A^{-1}, and 2 and 5 dry tons biosolids A^{-1} treatments and analyzed them for NO_3-N accumulation.

This report provides data for the 2014 crop year only. The reader is reminded that the 2014 North Bennett plots received biosolids at the same application rates in July or August 1994, 1996, 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012, and 2014. Considering these ten prior applications plus the most recent application, the recommended 2 dry tons A^{-1} biosolids rate for the 2014 growing season represents a cumulative addition of 22 dry tons A^{-1} biosolids for the life of the experiment or about 352 lbs. available N A^{-1}.

RESULTS AND DISCUSSION

Grain Yields, Protein and Grain and Soil Elemental Content

Sunflower yields averaged 588 pounds A^{-1} (Table 3) and were below the Colorado 2014 average yield of 1507 pounds A^{-1} (USDA NASS Colorado Field Office, 2015). The establishment of the sunflowers in the plots was not uniform, and there were multiple areas where the plant density was lower than the rest of the field. We believe that the poor establishment was not a result of the biosolids or fertilizer treatments since there was not a significant trend for the number of plants per plot. It was most likely due to a mechanical problem during planting.

As shown in Tables 3 and 4, neither commercial N fertilizer nor L/E biosolids applications had an effect on yield, seed protein content, or seed P, Cu, Ni, or Zn concentrations. All seed metal contents were well below the levels considered harmful to livestock (National Research Council, 1980).

Plant available nutrients from AB-DTPA extractions showed there was not an effect of the addition of biosolids or N fertilizer (Table 5 and 6). The AB-DTPA Cu concentration was higher compared to previous years and is most likely due to higher than average rainfall between sunflower harvest and soil sampling.

Biosolids Application Recommendation

We compared yields from N and biosolids plots at North Bennett to determine the N equivalency of the biosolids. However, there was no grain yield response to either N fertilizer or biosolids application, and thus we did not calculate a N equivalency relationship between biosolids andN-fertilizer treatments (Figure 1). In past growing seasons we have estimated that 1 dry ton of biosolids would supply the equivalent of 16 lbs of fertilizer N (Barbarick and Ippolito, 2000; Barbarick and Ippolito, 2007) for the winter-wheat crop. This approximation is used in planning long-term biosolids applications.

Nutrient Availability and Residual Soil NO_3-N

Neither the recommended 2 dry tons biosolids A^{-1} nor the 5 dry tons biosolids A^{-1} application rate significantly affected NO_3-N in the soil profile as compared to either the control or the 40 lbs N A^{-1} fertilizer application rate (Figure 2) except from 8 to 24 inches. From 8 to 24 inches there was no difference between the control, 40 lbs N A^{-1}, and 2 dry tons biosolids A^{-1}, but there was a significant increase with the application of 5 dry tons biosolids A^{-1}. Soil NO_3-N concentrations at all depths and for all treatments were less than 10 mg kg^{-1}.

SUMMARY

North Bennett sunflower seed yields were below the Colorado 2014 average yield of 1507 pounds A^{-1} (USDA NASS Colorado Field Office, 2015).

We observed an increase in soil AB-DTPA Cu but it was not a result of the addition of biosolids for N fertilizer. It was most likely due to the soil having been wet for an extended period prior to soil sampling compared to previous years. There was also an increase in soil NO_3-

N from 8 to 24 inches with the application rate of 5 dry tons biosolids A^{-1}, but there were no differences in the remainder of the soil profile.

We continue to recommend 2 dry tons biosolids application A^{-1}. Previous growing season results show that 1 dry ton biosolids A^{-1} is equivalent to 16 lbs N A^{-1} of fertilizer (Barbarick and Ippolito, 2000; Barbarick and Ippolito, 2007) for winter wheat. These approximations are used in planning long-term biosolids applications. We recommend that producers use soil testing and biosolids analyses along with appropriate yield goals to select a fertilizer program that will ensure optimum crop yields as well as environmental protection.

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Table 1. Monthly precipitation (Precip) in inches at the Bennett research site, 2010-2014. (Precipitation datalogger was installed in May, 2008).

	2010	2011	2012	2013	2014
	Precip., inches				
January	0.1	0.3	0.1	0.3	0.2
February	0.2	0.0	0.4	0.4	0.2
March	0.3	0.2	0.0	0.8	0.5
April	2.5	0.9	1.4	1.3	1.1
May	1.5	3.7	1.2	1.0	2.8
June	1.8	0.7	0.7	1.2	1.7
July	1.4	3.6	1.2	2.8	0.5
August	2.5	1.5	0.1	2.3	0.1
September	0.1	1.0	2.0	6.0	0.2
October	0.8	0.9	1.2	0.5	0.0
November	0.5	0.2	0.4	0.1	0.6
December	0.0	0.1	0.2	0.0	0.2
Total	11.7	13.1	8.9	16.7	8.1

Table 2. Average composition of Littleton/Englewood biosolids applied in 2014 compared to the Grade I and II biosolids limits.

Property	Dry Weight Concentration Littleton/Englewood	lbs. added per ton	Grade I Biosolids Limit¶	Grade II Biosolids Limit
Organic N (%)	5.2	104		
NO_3-N (%)	<0.01	---		
NH_4-N (%)	0.25	5		
Solids (%)	89.0	---		
P (%)	4.4	88		
Ag (mg kg^{-1}) †	7.6	0.015		
As (mg kg^{-1})	<0.001	<0.000001	41	75
Ba (mg kg^{-1})	344	0.69		
Be (mg kg^{-1})	0.08	0.0002		
Cd (mg kg^{-1})	1.70	0.0034	39	85
Cr (mg kg^{-1})	38.9	0.078	1200	3000
Cu (mg kg^{-1})	497	0.99	1500	4300
Pb (mg kg^{-1})	32.0	0.064	300	840
Hg (mg kg^{-1})	0.011	0.00002	17	57
Mn (mg kg^{-1})	456	0.912		
Mo (mg kg^{-1})	8.6	0.017	Not finalized	75
Ni (mg kg^{-1})	17.4	0.035	420	420
Se (mg kg^{-1})	8.9	0.018	36	100
Zn (mg kg^{-1})	1074	2.148	2800	7500

¶ Grade I and II biosolids are suitable for land application (Colorado Department of Public Health and Environment, 1996).

† mg kg^{-1} = parts per million.

Table 3. Effects of N fertilizer and biosolids on sunflower yield at North Bennett, 2014.

N fert. lbs. A^{-1}	Biosolids† dry tons A^{-1}	Yield lbs A^{-1}
0		588
20		672
40		532
60		392
80		644
100		364
Mean◊		532
LSD N rate¶		NS
	0	616
	1	280
	2	476
	3	840
	4	896
	5	700
Mean◊		644
LSD biosolids rate¶		NS
N vs. biosolids¶		NS

† Identical biosolids applications were made in 1994, 1996, 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012, and 2014; therefore, the cumulative amount is 11 times that shown.

◊ Means/LSD/N vs. biosolids do not include the controls.

¶ NS = not significant at 5% probability level; * = significant at the 5% probability level.

Table 4. Effects of N fertilizer and biosolids rates on protein and elemental concentrations of sunflower grain at North Bennett, 2014.

N fert. lbs N A^{-1}	Biosolids dry tons A^{-1} †	Protein %	P g kg^{-1}	Cu --------	Ni mg kg^{-1}	Zn --------
0		23.1	6.1	20.6	1.38	52
20		21.0	5.9	18.4	1.22	48
40		22.0	6.2	20.5	1.47	51
60		21.5	6.0	18.9	1.52	47
80		21.0	6.2	19.4	1.49	54
100		22.5	6.3	21.6	1.29	56
Mean§		21.6	6.1	19.8	1.40	51
Sign. N rates		NS	NS	NS	NS	NS
LSD						
	0	21.7	6.3	21.2	1.32	56
	1	21.0	6.3	21.1	1.68	55
	2	23.1	6.5	21.4	1.58	57
	3	21.3	6.5	21.2	1.68	59
	4	22.5	6.3	19.5	1.65	52
	5	23.5	6.2	19.7	1.67	49
	Mean	22.3	6.4	20.6	1.65	54
	Sign. biosolids rates	NS	NS	NS	NS	NS
	LSD					
	N vs biosolids	NS	**	NS	NS	**

† Identical biosolids applications were made in 1994, 1996, 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012, and 2014; therefore, the cumulative amount is 11 times that shown.

§ Means/LSDs/N vs biosolids do not include the controls (the zero rates).

¶ NS = not significant, * = significance at 5% probability level, ** = significance at 1% probability level, ND = non-detectable.

Table 5. Soil ABDTPA elemental concentrations for the 0 to 8 inches depth at harvest at North Bennett, 2014.

N fert. lbs N A^{-1}	Biosolids dry tons A^{-1}†	P	Cu	Ni	Zn
		---	mg	kg^{-1}	---
0		34	3.98	0.71	0.99
20		30	3.33	0.67	0.64
40		29	4.55	0.82	1.39
60		46	5.40	0.76	1.92
80		39	4.12	0.75	1.15
100		40	4.50	0.66	1.39
Mean§		36	4.31	0.73	1.25
Sign. N rates		NS	NS	NS	NS
LSD					
	0	27	3.63	0.62	0.80
	1	41	4.20	0.74	1.69
	2	39	4.78	0.71	2.02
	3	35	4.07	0.66	1.45
	4	44	6.25	0.80	3.15
	5	37	5.80	0.79	2.76
	Mean	37	4.79	0.72	1.98
	Sign. biosolids rates	NS	NS	NS	NS
	LSD				
	N vs biosolids	NS	NS	NS	NS

† Identical biosolids applications were made in 1994, 1996, 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012, and 2014; therefore, the cumulative amount is 11 times that shown.

§ Means/LSDs/N vs biosolids do not include the controls (the zero rates).

¶ NS = not significant, * = significance at 5% probability level, ** = significance at 1% probability level.

Table 6. Soil ABDTPA elemental concentrations for the 8 to 24 inches depth at harvest at North Bennett, 2014.

N fert. lbs N A^{-1}	Biosolids dry tons A^{-1}†	P	Cu	Ni	Zn
			mg	kg^{-1}	
0		6	2.07	0.38	0.00
20		9	2.19	0.41	0.09
40		6	1.94	0.33	0.00
60		8	2.09	0.35	0.00
80		10	2.21	0.38	0.10
100		6	2.04	0.33	0.00
Mean§		8	2.09	0.36	0.03
Sign. N rates		NS	NS	NS	NS
LSD					
	0	6	1.82	0.30	0.00
	1	5	1.79	0.28	0.00
	2	7	2.05	0.40	0.00
	3	6	1.94	0.31	0.00
	4	7	2.09	0.32	0.02
	5	7	1.91	0.30	0.07
	Mean	6	1.93	0.32	0.01
	Sign. biosolids rates	NS	NS	NS	NS
	LSD				
	N vs biosolids	NS	NS	NS	NS

† Identical biosolids applications were made in 1994, 1996, 1998, 2000, 2002, 2004, 2006, 2008, 2010, 2012, and 2014; therefore, the cumulative amount is 11 times that shown.

§ Means/LSDs/N vs biosolids do not include the controls (the zero rates).

¶ NS = not significant, * = significance at 5% probability level, ** = significance at 1% probability level.

Figure 1. North Bennett sunflower yields in 2014 as affected by either N fertilizer or biosolids application.

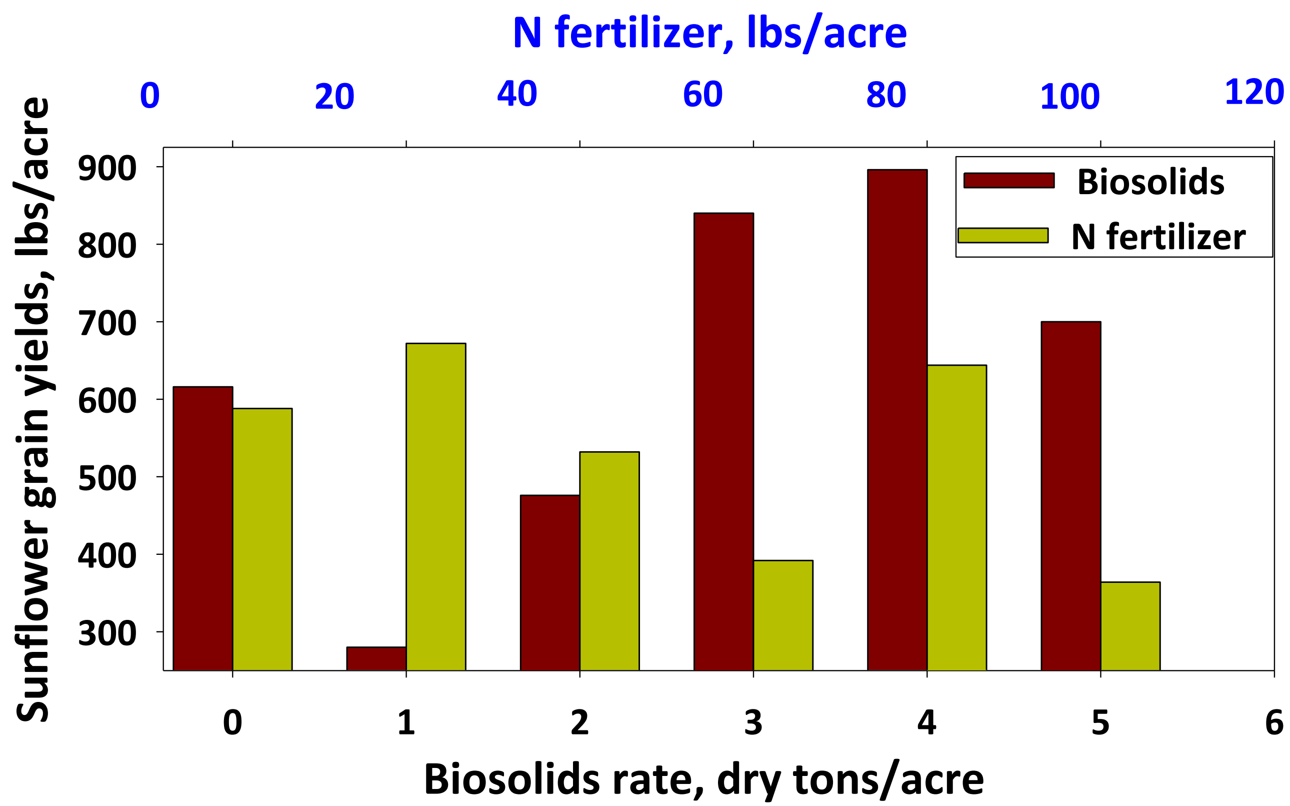
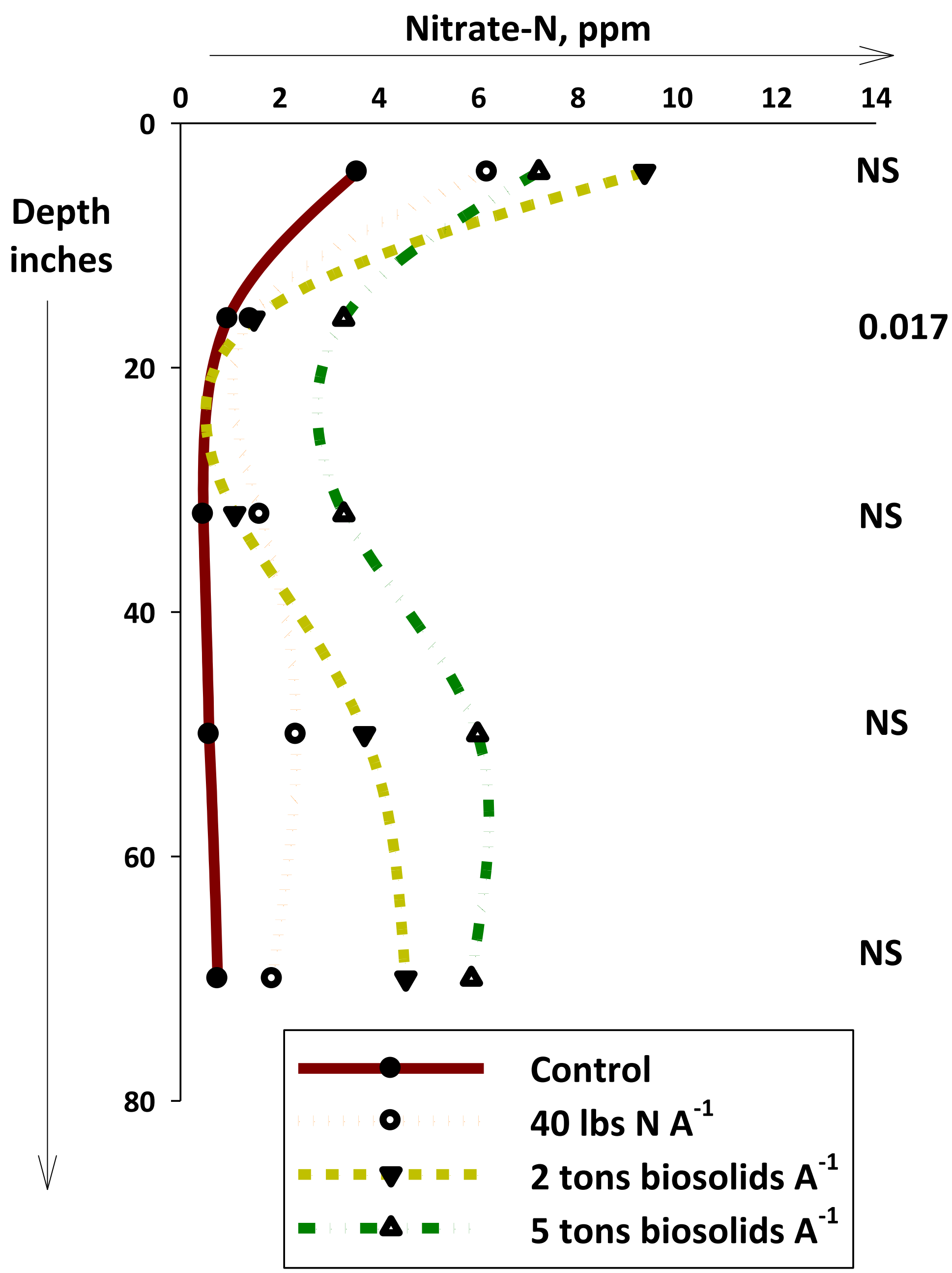


Figure 2. North Bennett harvest sunflower soil nitrate-N, 2014.



NS = non significant.